



CALIFORNIUM-252: A NEW ISOTOPIC SOURCE FOR NEUTRON RADIOGRAPHY

bу

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Nuclear reactors are the usual source of neutrons for radiography primarily because of their intense neutron beams.

Much of the development work in neutron radiography was directed at problems peculiar to the nuclear industry, and the laboratories engaged in this work had ready access to reactors. Although there are still many applications for neutron radiography within the nuclear industry, potential uses in other industrial and scientific fields are increasing rapidly. It is impractical in some cases to bring the equipment to a reactor to be radiographed; in other cases, it adds to the cost and time to make the tests. Therefore, if neutron radiography is to have widespread use, intense transportable neutron sources are required that can be used in plants, in laboratories, and in the field.

Californium-252, an intense neutron emitting radioisotope, is a promising new source for radiography. A gram of 252 Cf emits $^{2.34}$ x $^{10^{12}}$ neutrons per second by spontaneous fission. 124 Sb-Be is the only other isotopic source with a high neutron yield that has attracted interest for neutron radiography. $^{(1,2)}$ A comparison of the characteristics of 252 Cf and 124 Sb-Be sources with a yield of 5 x $^{10^{10}}$ neutrons per second, which is adequate for radiography, is shown in Table 1.

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Five thousand curies of ¹²⁴Sb are required for an emission rate of 5 x 10¹⁰ neutrons per second while only 11 curies of ²⁵²Cf are needed. ¹²⁴Sb-Be inefficiently produces neutrons by the reaction of gamma decay of ¹²⁴Sb with beryllium. A well-designed ¹²⁴Sb-Be source, such as described by Hennelly ⁽³⁾, will emit 10⁷ neutrons per second per curie; in contrast, ²⁵²Cf emits ^{4.4} x 10⁹ neutrons per second per curie. The very small volume of the ²⁵²Cf source provides essentially a point source of neutrons. The comparatively large volume of the ¹²⁴Sb-Be source is due to the large amount of beryllium required for an efficient source. When good imaging techniques for fast neutrons are developed, a point source would provide geometric magnification to improve radiographic magnification, as is often done with X-radiography.

Californium-252 neutrons have an average energy of 2.3 MeV; the neutron spectrum of ²⁵²Cf is shown in Figure 1. The 24 keV neutrons from ¹²⁴Sb-Be require less moderation for thermal neutron radiography, but the neutron energy of ¹²⁴Sb-Be is too low for fast neutron radiography.

The gamma dose rate from ¹²⁴Sb-Be is 5000 times greater than from ²⁵²Cf. Some of the methods of detecting neutrons for radiography cannot be used in the presence of high levels of gamma radiation, such as is associated with ¹²⁴Sb-Be. Other detection methods become complicated and expensive because of the need for gamma discrimination or reduction. The high gamma radiation from ¹²⁴Sb-Be will require great attention to the protection of personnel during radiography. The magnitude of the gamma radiation is illustrated by this comparison. The dose rate a few inches from a typical ⁴⁰⁰ kVp industrial radiography generator is 12 R/minute; the gamma dose rate at two inches from a 5000 curie ¹²⁴Sb-Be source is 10⁵ R/minute.

At a cost of \$10³ per milligram, which is an order of magnitude estimate over the next ten years, the ²⁵²Cf source offers the most favorable combination of initial investment plus replenishment costs. The initial costs of ²⁵²Cf and ¹²⁴Sb-Be sources are approximately the same; however, the annual replenishment costs are much higher for the ¹²⁴Sb-Be source because of its shorter half-life. The values shown in Table 1 are based on the costs of the radionuclides only, and they do not include fabrication and shipping charges.

Because a ²⁵²Cf neutron source requires no target material, fabrication cost would be less than for the ¹²⁴Sb-Be source. Shipping charges associated with replenishing the short-lived ¹²⁴Sb-Be would be significant, as much as 20% of the annual replenishment costs, due to the 2-ton shipping cask.

In addition to reactors and isotopic neutron sources, accelerators have been proposed as a source of neutrons for radiography. Sealed neutron generating tubes, developed in the past few years, with yields as high as 10^{11} neutrons per second initially cost about the same as a 252 Cf source with the same neutron yield. Where a continuous source of neutrons is required, such as for radiographic inspection in industrial quality control, the cost per neutron from a 252 Cf source is considerably less than from an accelerator. The 252 Cf source requires no maintenance and can be transported easily to work areas or remote field locations. Also, the neutron emission from a 252 Cf source is constant over long periods of time, and it can be determined without supplementary measurements.

In summary, ²⁵²Cf is a promising new neutron source for radiography. Although only a few milligrams are now available to explore benefits of this radionuclide in radiography, several grams may be available in the early 1970's for developmental work.

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Characteristics of ²⁵²Cf and ¹²⁴Sb-Be Sources with Yields of 5 x 10¹⁰ neutrons/second

	252 _{Cf}	124Sb-Be
Curies	11	5000
Volume (cc)	<1	200
Neutron Energy (avg.)	2.3 MeV	24 keV
Gamma Dose Rate (R/hr at 1 meter)	2.9	1.4 x 10 ⁴
Half-life	2.6 years	60 days
Initial Cost	\$20,000	\$25,000
Annual Replenishment Cost	\$ 4,000	\$76,000

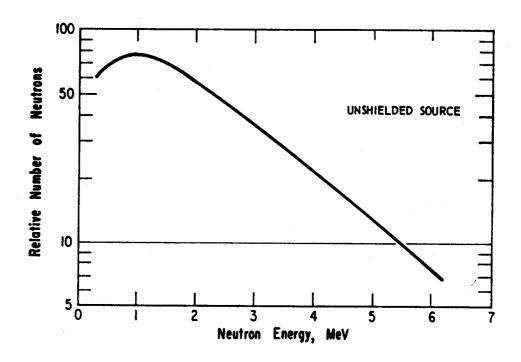


FIG. 1 NEUTRON SPECTRUM OF 252Cf